AEDC-TSR-81-V13 ADDENDUM

LEVEL III (2)

WIND TUNNEL TESTS OF THE SPACE SHUTTLE FOAM INSULATION WITH SIMULATED DEBONDED REGIONS

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Calspan Field Services, Inc.

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Final Report for Period August 10, 1981

ARNOLD ENGINEERING DEVELOPMENT CENTER
ARNOLD AIR FORCE STATION, TENNESSEE
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Wind tunnel tests of the Space Shuttle External Tank foam insulation, with simulated lightning protectors, were conducted in the von Karman Gas Dynamics Facility Tunnel C. The tests were conducted to examine three lightning conductive coating materials for debris production potential in simulated convective heating environments. The material samples were tested using the wedge technique. The tests were run at a free-stream Mach number 10 and a free stream total temperature of 1,900°R. The wedge angle was varied to provide test conditions which were representative of those expected during launch.

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CONTENTS

APPENDIXES

NOMENCLATURE

(See AEDC-TSR-81-V13)

1.0 INTRODUCTION

The work reported herein was conducted by the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), under Program Element 921E02, Control Number 9E02 at the request of the National Aeronautics and Space Administration (NASA), Marshall Space Flight Center (MSFC), Huntsville, Alabama for the Martin-Marietta Corporation (Michoud Operations), New Orleans, Louisiana. The Martin Marietta Corporation project engineer was Mr. Steve Copsey, and the NASA/MSFC project manager was Mr. John Warmbrod. The results were obtained by Calspan Field Services, Inc./AEDC Division, operating contractor for the Aerospace Flight Dynamics testing effort at the AEDC, AFSC, Arnold Air Force Station, Tennessee. The tests were conducted in the von Karman Gas Dynamics Facility (VKF), under AEDC Project No. C342VC. This was the second test entry on this project. The previous tests were reported in AEDC-TSR-81-V13 and this is a continuation (Addendum) to that report.

The conductive coating used for lightning protection on the External Tank of the first space shuttle flight proved to be a potential debris source due primarily to application in relatively thick sections. This test examined three alternate conductive coating materials for debris production potential in convective heating environments simulating flight. The materials used were of much lower viscosity than the previously used material to allow application in thinner coatings. In addition, an experimental deicing compound was applied on several samples to observe any effects the compound might have on the spray-on foam.

A total of 23 samples was tested in the 50-in.-diam Hypersonic Wind Tunnel (C) at the VKF on August 10, 1981. Data were recorded at Mach 10 with tunnel stilling chamber conditions of 1,800 psia and 1,900°R. The nominal wedge angle (WA) varied from 14 to 24 deg to produce local cold wall heating rates ranging from 0.6 to 10 BTU/ft^2-sec.

A summary of the test data transmitted to the sponsor (NASA/MSFC) and the user (MMC) is presented in Table 5.

Inquiries to obtain copies of the test data should be directed to NASA/MSFC/ED33, Marshall Space Flight Center, Huntsville, AL 35812. A microfilm record has been retained in the VKF at AEDC.

2.0 APPARATUS

2.1 TEST FACILITY

(See AEDC-TSR-81-V13)

2.2 TEST ARTICLE

A pretest photograph of a typical specimen is shown in Fig. 9. The specimens were basically flat insulation panels consisting of a 0.13-in. aluminum support plate covered with a 0.6-in. layer of super light ablator (SLA, Mat'l SLA-561) and a 0.75-in. layer of spray-on foam insulator (SOFI, Mat'l CPR-488). Strips of conducting paint of

different thicknesses were placed on the foam. The specimens were attached to the VKF materials wedge for testing as shown in Fig. 10. Installation of the wedge in Tunnel C is illustrated in Fig. 11.

2.3 TEST INSTRUMENTATION

The instrumentation consisted of 9 Gardon gages located on the forward 17.5 inches of the wedge as shown in Fig. 10b.

The Gardon gages used were a special high temperature type, 0.25-in. in diam, with a 0.010-in. thick sensing disk. Each gage had a Chromel-® Alumel®thermocouple to provide the gage edge temperature. These temperatures, together with the gage output, were used to determine the gage surface temperatures and corresponding heat transfer rate, which was then used to calculate the local heat transfer coefficient. These heat transfer coefficients were used to confirm the flow conditions over the sample specimens.

3.0 TEST DESCRIPTION

3.1 TEST CONDITIONS

A summary of the nominal test condition is given below:

M	PT, psia	TT, °R	P, psia
10.10	1800	1900	0.038

A test summary showing the configurations tested and the variables for each is presented in Table 6.

3.2 TEST PROCEDURES

(See AEDC-TSR-81-V13)

3.3 DATA REDUCTION

(See AEDC-TSR-81-V13)

3.4 UNCERTAINTY OF MEASUREMENTS

(See AEDC-TSR-81-V13)

4.0 DATA PACKAGE PRESENTATION

A complete set of all photographic data and tabulated data for this test has been provided to Martin Marietta Corporation. Photographic data which showed significant testing results and a complete set of tabulated data have been provided to NASA/Marshall Space Flight Center/ED33, Huntsville, Alabama. All test specimens for this test have been returned to Martin Marietta Corporation.

A representative posttest photograph is shown in Fig. 12. This is the same test panel shown in the pretest photograph in Fig. 9.

Samples of the tabulated data are presented in Appendix IV. A copy of all data except photographs has been retained on microfilm in the VKF.

REFERENCES

(SEE AEDC-TSR-81-V13)

APPENDIX I

ILLUSTRATIONS

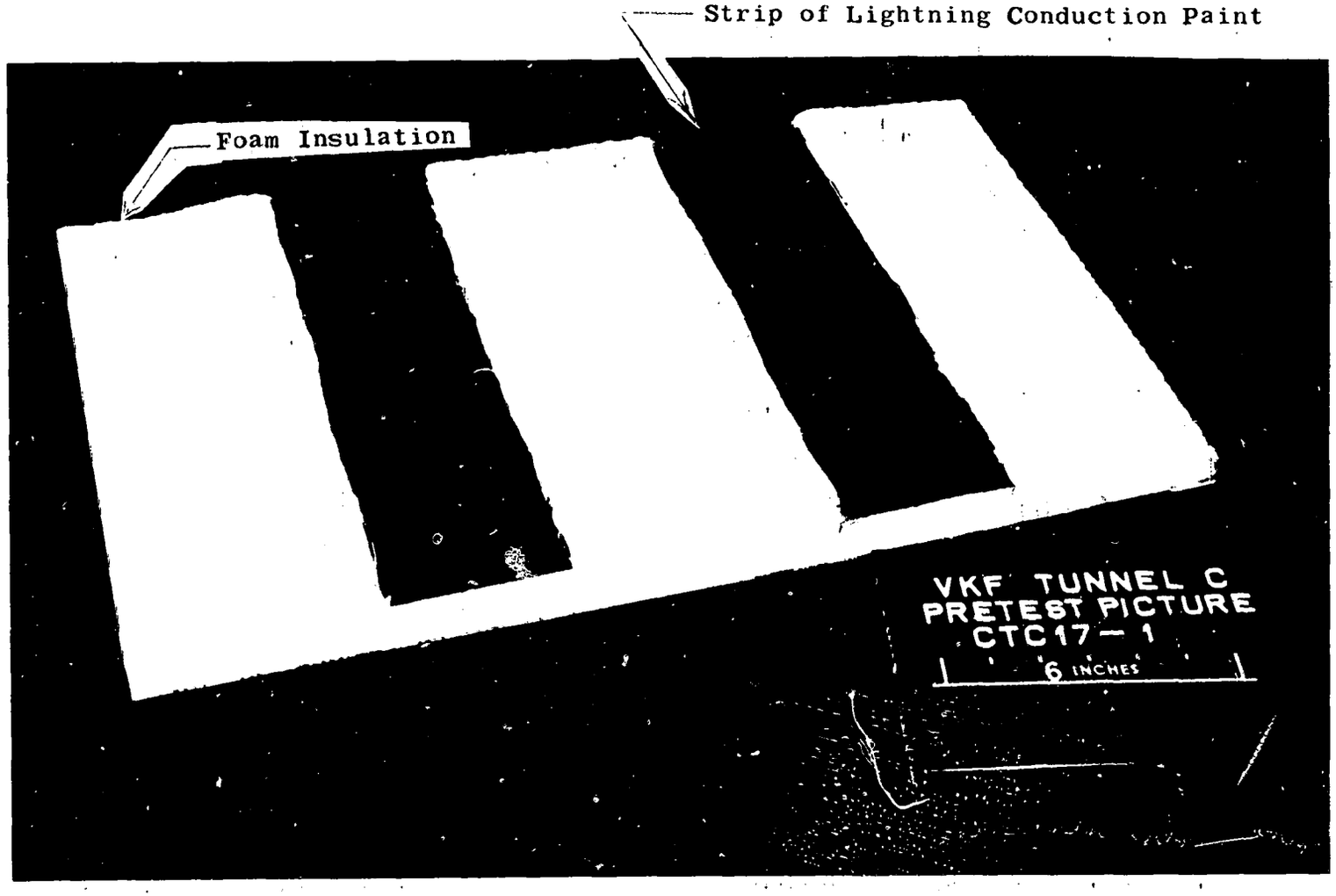

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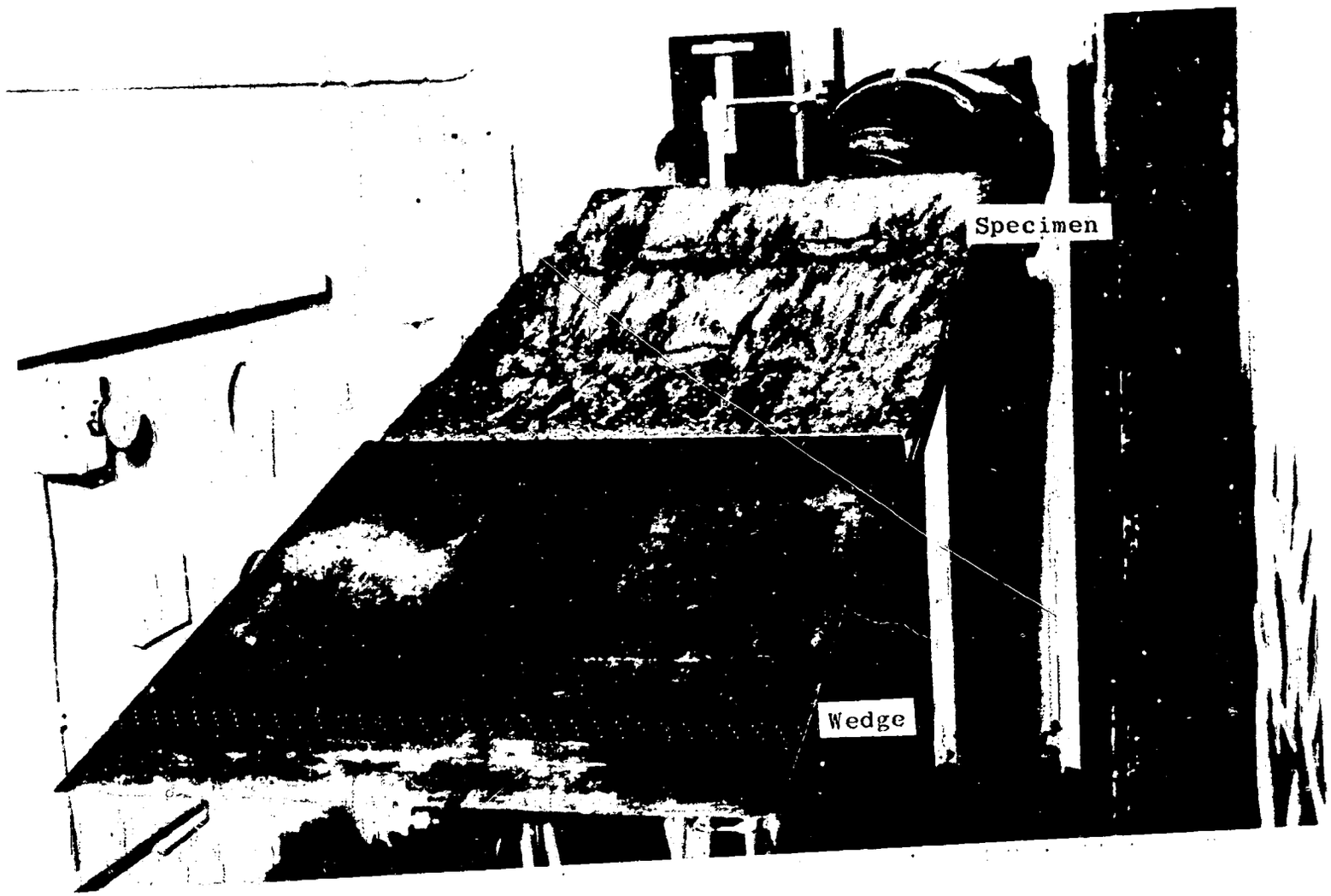
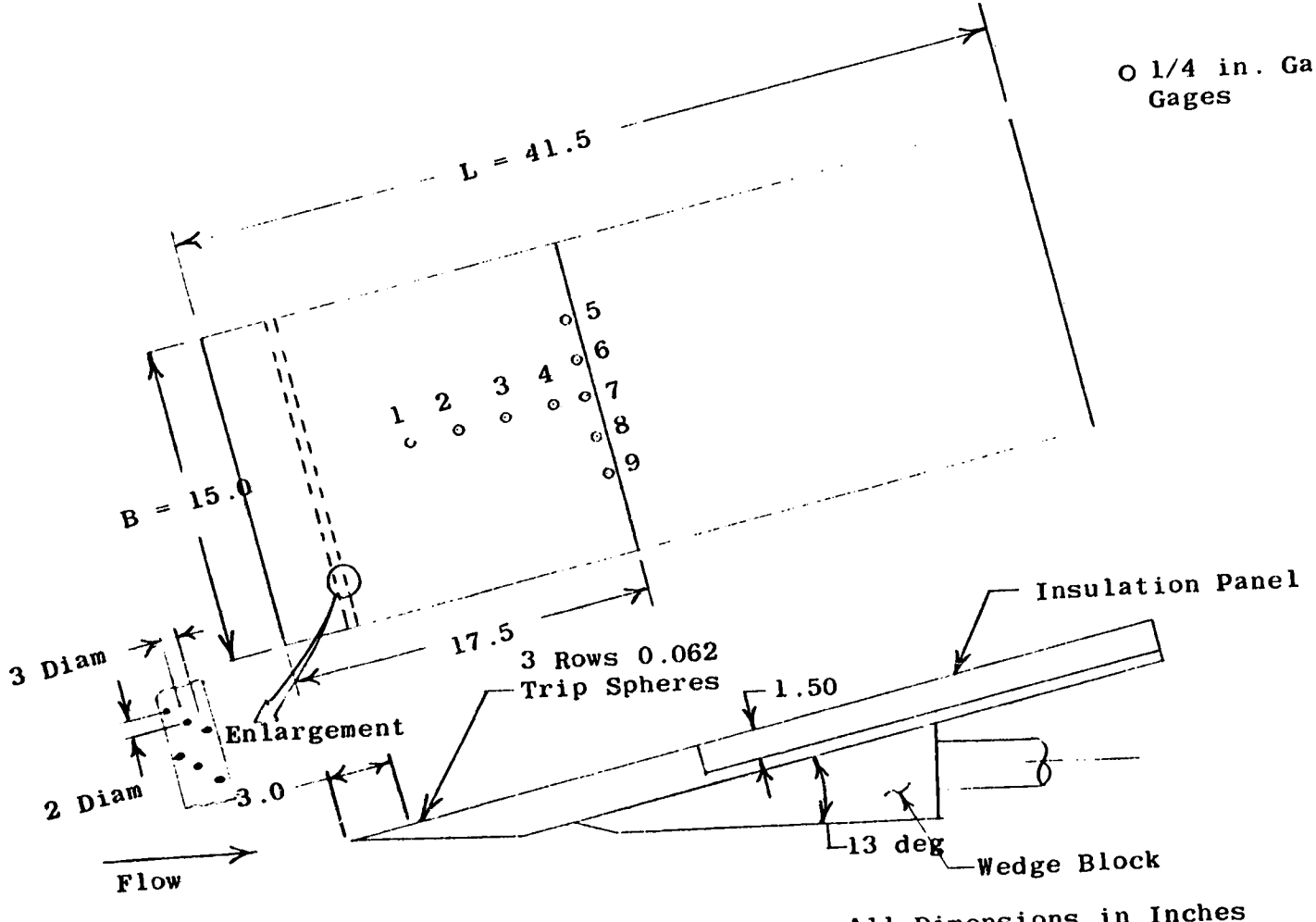
Figure 9. Typical Specimen Pretest Photograph



a. Photograph of Specimen on Wedge

Figure 10. Installation of Test Specimen on Wedge



b. Sketch of Materials Testing Wedge with Instrumentation

Figure 10. Concluded

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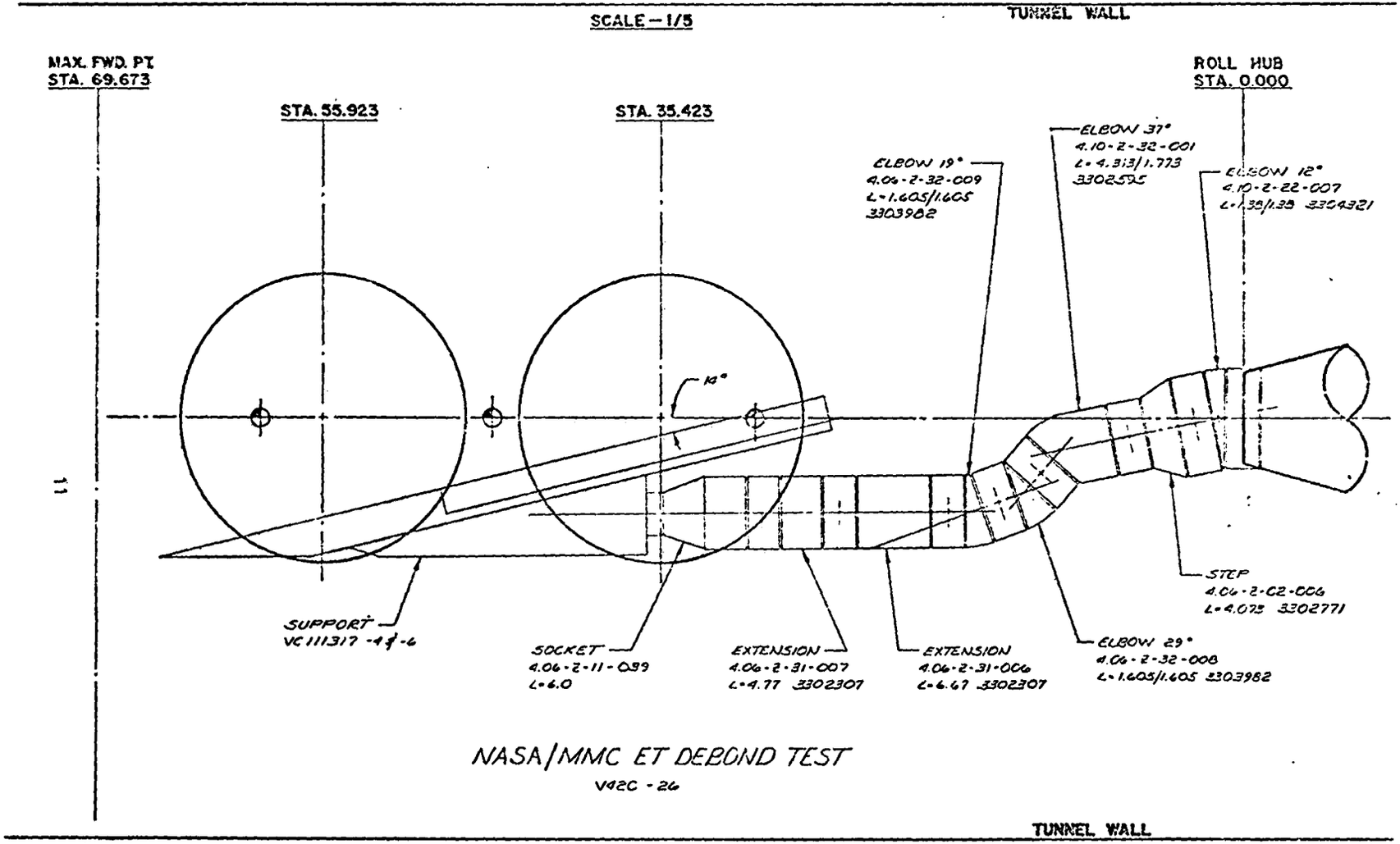
a. Installation Photograph

Figure 11. Installation in Tunnel C



b. Installation Sketch

Figure 11. Concluded

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Figure 12. Typical Posttest Photograph

APPENDIX II

TABLES

TABLE 5. Data Transmittal Summary

The following items were transmitted to the Sponsor and the User:

	Sponsor	User
	John Warmbrod ED33 Marshall Space Flight Center, AL 35812	Steve Copsey Martin Marietta Dept. 3571 P.O. Box 29304 13800 Gentilly Rd. New Orleans, LA 70189
Item	No. of Copies	No. of Copies
Test Summary Report	1	1
Pre- and Posttest Photographs* (8x10)	1	1
70 mm Stills: contact prints and duplicate negatives (Runs 1-23)	1	1
70 mm shadowgraphs: contact prints and duplicate negatives (Runs 1-23)	1	1
16 mm movies, top view: work prints and optical masters (Runs 1-23)	1	1
16 mm movies, side view: work prints and optical master (Runs 1-23)	1	1
Final Data Package	1	1

* Pretest photos of specimens CTC17-20, 21, 23, 24 were taken by Martin Marietta.

TABLE 6. Test Summary

PT = 1800 psia TT = 1900°R

RUN NO.	MODEL ID CTC 17-	CONFIGURATION CODE	WEDGE ANGLE	TIME EXPT	APPROX Q-DOT-O
1	1	1	14	73.81	6
2	2	2	19	31.01	8
3	3	3	24	20.73	10
4	4	4	14	42.58	6
5	5	5	19	31 56	8
6	6	6	24	21.56	10
7	7	7	14	45.78	6
8	8	8	19	32.25	8
9	9	9	24	21.77	10
10	10	10	14	3.13	6
11	11	11	19	32.42	8
12	12	12	24	22.00	10
13	16	16	14	44.16	6
14	17	17	19	48.15	8
15	18	18	14	42.64	6
16	19	19	19	33 03	8
17	13	13	14	42.68	6
18	14	14	19	32.12	8
19	15	15	24	22.89	10
20	20	20	14	42.81	6
21	21	21	19	33.10	8
22	23	23	19	62.34	8
23	24	24	24	42.88	10

The approximate QDOT-0 level is based on previous calibration data.

APPENDIX III

REFERENCE HEAT-TRANSFER COEFFICIENT

(SEE AEDC-TSR-81-V13)

APPENDIX IV

SAMPLE TABULATED DATA

ARVIN/CALSPAN FIELD SERVICES, INC.
AEDC DIVISION
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
NASA/MMC ET TPS DEMONS (PHASE II)
PAGE 1

DATE COMPUTED 21-AUG-81
TIME COMPUTED 15:12:56
DATE RECORDED 10-AUG-81
TIME RECORDED 2:20:51
PROJECT NUMBER V--C-26

RUN	SAMPLE	ALPHI D.C.	P DEG	CM IN	TAPEZERO SEC	TIMEREC HOUR	MIN	SEC	MSEC	TIMEEXPT SEC
1	CTC17- 1	-0.04	14.04	25.00	3.747	2	21	26	573	73.80

M	PT PSIA	TT DEG R	T DEG R	P PSIA	Q PSIA	V FT/SEC	RHO LBM/FT3	MU LBF-SEC/FT2	RE FT-1	ITT BTU/LBM
10.10	1748.93	1900.7	93.6	3.783E-02	2.70	4788.9	1.091E-03	7.533E-08	2.156E+06	4.784E+02

PIC NO.	TIME SEC	TIMEEXP SEC
1	4.27	2.17
2	6.31	4.21
3	8.35	6.25
4	10.45	8.35
5	12.49	10.39
6	14.53	12.43
	SHADOWGRAPH TAKEN AT 14.1 SECONDS.	
7	16.63	14.53
8	18.65	16.55
9	20...	18.62
10	22.78	20.68
11	24.85	22.75
12	26.92	24.82
13	28.97	26.87
14	31.04	28.93
15	33.10	31.00
16	35.17	33.07
17	37.24	35.13
18	39.31	37.20
19	41.37	39.27
20	43.44	41.33
21	45.50	43.40
22	47.55	45.45
23	49.62	47.52
24	51.68	49.58
25	53.76	51.65
26	55.82	53.72
27	57.87	55.76
28	59.91	57.80
29	62.00	59.90
30	64.07	61.96
31	66.14	64.04
32	68.19	66.08
	73.80 MODEL HAS LEFT CENTERLINE	

Sample 2. Photograph History Data

ARVIN/CAL : FIELD SERVICES, INC.
AEDC DIV :I
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
NASA/MMC ET TPS DEBOND (PHASE II)

DATE COMPUT 10-AUG-81
TIME COMPUT 02:49:09
DATE RECORDED 10-AUG-81
TIME RECORDED 2:21:22
PROJECT NUMBER V C-20

PAGE 2

RUN	SAMPLE	ALPHA DEG	CA DEG	CG IN
1	C1C17- 1	-0.07	14.07	25.00

M	PT PSIA	TT DEG R	T DEG R	P PSIA	Q PSIA	V FT/SEC	RHO LBM/FT3	MU LBF-SEC/FT2	RE FT-1	ITT BTU/LBM
10.10	1749.23	1900.7	93.6	3.784E-02	2.70	4788.9	1.091E-03	7.533E-08	2.156E+06	4.784E+02

HEDGE GARDON GAGE DATA

GAGE	X/L	Y/L	TGF (DEG R)	TW (DEG R)	QDOT (BTU/FT2-SEC)	H(TT) (BTU/FT2-SEC-R)	QDOT-Q (BTU/FT2-SEC)
1	0.14	0.00	550.1	575.6	6.27	4.733E-03	6.821E+00
2	0.22	0.00	548.7	573.8	5.72	4.311E-03	6.212E+00
3	0.29	0.00	546.4	574.6	6.33	4.770E-03	6.874E+00
4	0.36	0.00	544.2	562.0	6.12	4.571E-03	6.586E+00
5	0.41	0.30	544.2	563.1	4.70	3.514E-03	5.063E+00
6	0.41	0.15	545.1	570.1	5.53	4.155E-03	5.987E+00
7	0.41	0.00	545.2	565.7	6.00	4.495E-03	6.478E+00
8	0.41	-0.15	546.8	573.4	5.73	4.314E-03	6.217E+00
9	0.41	-0.30	546.8	573.7	5.72	4.312E-03	6.214E+00

Sample 3. Gardon Gage Data